

TITLE OF THE INVENTION  
Multi-Piece Solid Golf Ball

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to golf balls which have an outstanding flight performance, an excellent scuff resistance and a soft "feel" upon impact.

Prior Art

Golf balls have hitherto been modified and improved in a variety of ways to address the numerous and diverse requirements of golfers. The present assignee, among others, has already disclosed many outstanding golf balls.

For example, JP-A 9-313643 describes an all-round golf ball which has excellent flight characteristics and durability, a good, soft feel on impact, and controllability.

JP-A 10-305114 discloses a golf ball having a dramatically increased carry and a good feel on impact.

JP-A 11-114094 teaches a golf ball in which deflection by the solid core and the relative thicknesses and hardnesses of the cover and the mantle have been optimized so to provide a good trajectory and increased carry on shots with a driver, suitable spin characteristics and good controllability on approach shots, and excellent feel on impact and durability.

JP-A 2000-225209 relates to golf balls with an excellent overall performance that have the feel, durability and rebound characteristics required of a ball construction subject to limitations with respect to solid core deformation, hardness of the cover and the mantle and dimple characteristics, and that also have excellent flight characteristics.

JP-A 2001-218873 describes a golf ball of outstanding feel, controllability and flight performance--including carry, in which the mantle and/or cover are formed of specific

materials, and in which the respective Shore D hardnesses of the solid core center and surface and of the mantle and the cover are such as to satisfy the following relationship:  
solid core center hardness  $\leq$  mantle hardness  $\leq$  cover hardness.

5 JP-A 2002-210042 discloses a golf ball having a very soft feel on impact yet good durability and also having a low spin, high angle of elevation and high rebound that together provide increased carry. This prior-art golf ball is achieved by specifying all of the following: center hardness,  
10 surface hardness and diameter of the solid core, mantle hardness, thickness and material, cover hardness, thickness and material, difference in hardness between mantle and solid core surface, difference in hardness between cover and mantle, relationship between hardness gradient from mantle to cover  
15 and hardness gradient from center of core to mantle, and dimple arrangement.

JP-A 8-276033 teaches a way of obtaining a solid golf ball having a good feel on impact and a long carry by setting the difference A-B between the compression deflection A by  
20 the core when subjected to a final load of 130 kgf from an initial load of 10 kgf and the compression deflection B by the ball when subjected to a final load of 130 kgf from an initial load of 10 kgf within a specific range.

These prior-art golf balls all have an excellent feel  
25 and an excellent carry and other flight characteristics, and can be suitably adapted to various requirements dictated by the skill level of the golfer and the intended use of the ball (e.g., recreational or competitive). Yet, given the ever-high expectations of golfers, there exists a need for  
30 golf balls endowed with an even better performance.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide golf balls which have excellent flight  
35 characteristics and scuff resistance, and which also have a soft feel on impact.

We have found that multi-piece solid golf balls constructed of a solid core, a mantle of at least one layer and a cover can be conferred with better flight characteristics, a higher scuff resistance and a softer feel on impact than prior-art golf balls by having the solid core made of a specific rubber composition and endowed with a specific degree of flexibility and diameter, having the mantle made of a specific thermoplastic resin composition and endowed with a specific thickness and hardness, having the cover made of a specific resin composition and endowed with a specific thickness and hardness, and setting the flexibility of the overall golf ball within a specific range.

Accordingly, this invention provides a multi-piece solid golf ball constructed of a solid core, a mantle of at least one layer which encloses the core, and a cover which encloses the mantle, wherein the solid core is made of a rubber composition comprising (A) 100 parts by weight of a base rubber that contains 60 to 100 wt% of a polybutadiene of at least 60% cis-1,4 structure and synthesized using a rare-earth catalyst, (B) 0.1 to 0.8 part by weight of an organic peroxide, (C) an unsaturated carboxylic acid and/or a metal salt thereof, (D) an organic sulfur compound and (E) an inorganic filler, has a deflection when subjected to a load of 980 N (100 kgf) of 3.0 to 6.0 mm, and has a diameter of 30 to 40 mm; the mantle of at least one layer is made of a thermoplastic resin composition, has a thickness per layer of 0.5 to 2.0 mm, and includes an outermost layer which is in contact with the cover and has a Shore D hardness of 20 to 60; the cover is made of a material composed of a heated mixture of (F) at least one selected from the group consisting of olefin/unsaturated carboxylic acid copolymers, olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymers and metal ion neutralization products thereof, (G) a polyurethane elastomer and (H) an organic or inorganic basic compound, has a thickness of 0.5 to 2.5 mm and a Shore D hardness of 50 to 70, and satisfies the condition (Shore D hardness of mantle outermost layer)  $\leq$

(Shore D hardness of cover); and the golf ball has a deflection when subjected to a load of 980 N (100 kgf) of 3.0 to 5.0 mm.

The polybutadiene is typically a modified  
5 polybutadiene prepared by synthesis using a neodymium catalyst, followed by reaction with a terminal modifier.

Preferably, the rubber composition includes (A) 100 parts by weight of a base rubber containing 60 to 100 wt% of a polybutadiene of at least 60% cis-1,4 structure and  
10 synthesized using a rare-earth catalyst, (B) 0.1 to 0.8 part by weight of at least two kinds of organic peroxide, (C) 10 to 60 parts by weight of an unsaturated carboxylic acid and/or a metal salt thereof, (D) 0.1 to 5 parts by weight of an organic sulfur compound, and (E) 5 to 80 parts by weight  
15 of an inorganic filler.

According to one preferred embodiment, the thermoplastic resin composition making up the mantle is composed of 100 parts by weight of resin components which include a base resin of (P) an olefin/unsaturated carboxylic  
20 acid binary random copolymer and/or a metal ion neutralization product of an olefin/unsaturated carboxylic acid binary random copolymer in admixture with (Q) an olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer and/or a metal ion  
25 neutralization product of an olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer in a weight ratio P/Q of 100:0 to 25:75, and (R) a non-ionomeric thermoplastic elastomer in a weight ratio (P+Q)/R of 100:0 to 50:50; (S) 5 to 80 parts by weight of a  
30 fatty acid or/or fatty acid derivative having a molecular weight of 280 to 1,500; and (T) 0.1 to 10 parts by weight of a basic inorganic metal compound capable of neutralizing un-neutralized acid groups in the base resin and component S.

According to another preferred embodiment, the  
35 thermoplastic resin composition making up the mantle is a polyester elastomer.

Preferably, the mantle consists of an inner layer and an outer layer.

Typically the golf ball cover bears a plurality of dimples on a surface thereof. Each dimple has a spatial volume below a planar surface circumscribed by an edge of the dimple and having a surface area circumscribed by the dimple edge on a hypothetical sphere represented by the surface of the golf ball cover were it to have no dimples. It is preferable for the golf ball to have a dimple volume occupancy VR, defined as the ratio of the sum of the individual dimple volumes to the volume of the hypothetical sphere, of 0.70 to 1.00%, and a dimple surface coverage SR, defined as the ratio of the sum of the individual dimple surface areas to the surface area of the hypothetical sphere, of 70 to 85%.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows exemplary arrangements of dimples of sets A and C in Table 4 on golf balls.

FIG. 2 shows exemplary arrangements of dimples of set B in Table 4 on golf balls.

#### DETAILED DESCRIPTION OF THE INVENTION

The solid core in the golf ball of the invention is made of a rubber composition which includes:

- (A) a base rubber that contains 60 to 100 wt% of a polybutadiene of at least 60% cis-1,4 structure and synthesized using a rare-earth catalyst,
- (B) an organic peroxide,
- (C) an unsaturated carboxylic acid and/or a metal salt thereof,
- (D) an organic sulfur compound, and
- (E) an inorganic filler.

In component A, which is a base rubber that contains 60 to 100 wt% of a polybutadiene of at least 60% cis-1,4 structure and synthesized using a rare-earth catalyst, the content of cis-1,4 units in the polybutadiene is at least 60%,

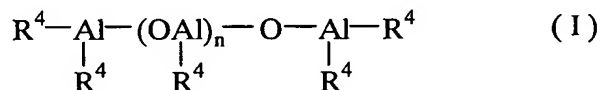
preferably at least 80%, more preferably at least 90%, and most preferably at least 95%. At a cis-1,4 unit content of less than 60%, suitable resilience is not achieved.

The polybutadiene in the invention is synthesized using a rare-earth catalyst. A known rare-earth catalyst may be used for this purpose. Exemplary catalysts include lanthanide series rare-earth compounds in combination with organoaluminum compounds, alumoxanes, halogen-bearing compounds or Lewis bases.

Examples of suitable lanthanide series rare-earth compounds include halides, carboxylates, alcoholates, thioalcoholates and amides of atomic number 57 to 71 metals.

Organoaluminum compounds that may be used include those of the formula  $\text{AlR}^1\text{R}^2\text{R}^3$  (wherein  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^3$  are each independently a hydrogen or a hydrocarbon residue of 1 to 8 carbons).

Preferred alumoxanes include compounds of the structures shown in formulas (I) and (II) below. The alumoxane association complexes described in *Fine Chemical* 23, No. 9, 5 (1994), *J. Am. Chem. Soc.* 115, 4971 (1993), and *J. Am. Chem. Soc.* 117, 6465 (1995) are also acceptable.



In the above formulas,  $\text{R}^4$  is a hydrocarbon residue having 1 to 20 carbon atoms, and  $n$  is 2 or a larger integer.

Examples of halogen-bearing compounds that may be used include aluminum halides of the formula  $\text{AlX}_n\text{R}_{3-n}$  (wherein  $\text{X}$  is a halogen;  $\text{R}$  is a hydrocarbon group of 1 to 20 carbons, such as an alkyl, aryl or aralkyl; and  $n$  is 1, 1.5, 2 or 3); strontium halides such as  $\text{Me}_3\text{SrCl}$ ,  $\text{Me}_2\text{SrCl}_2$ ,  $\text{MeSrHCl}_2$  and  $\text{MeSrCl}_3$  (wherein "Me" stands for methyl); and other metal

halides such as silicon tetrachloride, tin tetrachloride and titanium tetrachloride.

The Lewis base can be used to form a complex with the lanthanide series rare-earth compound. Illustrative examples  
5 include acetylacetone and ketone alcohols.

In the practice of the invention, the use of a neodymium catalyst in which a neodymium compound serves as the lanthanide series rare-earth compound is advantageous because it enables a polybutadiene rubber having a high  
10 cis-1,4 unit content and a low 1,2-vinyl unit content to be obtained at an excellent polymerization activity. Preferred examples of such rare-earth catalysts include those mentioned in JP-A 11-35633.

To achieve a polybutadiene having a cis unit content  
15 within the above range and a desirable polydispersity  $M_w/M_n$ , the polymerization of butadiene in the presence of a rare-earth catalyst containing a lanthanide series rare-earth compound is carried out at a butadiene/(lanthanide series rare-earth compound) molar ratio of preferably 1,000 to  
20 2,000,000, and especially 5,000 to 1,000,000, and at an  $AlR^1R^2R^3$ /(lanthanide series rare-earth compound) molar ratio of 1 to 1,000, and especially 3 to 500. It is also preferable for the (halogen compound)/(lanthanide series rare-earth compound) molar ratio to be 0.1 to 30, and  
25 especially 0.2 to 15, and for the (Lewis base)/(lanthanide series rare-earth compound) molar ratio to be 0 to 30, and especially 1 to 10.

The polymerization of butadiene in the presence of a rare-earth catalyst may be carried out either in a solvent or  
30 by bulk polymerization or vapor phase polymerization without the use of solvent, and at a polymerization temperature in a range of generally  $-30^\circ C$  to  $150^\circ C$ , and preferably 10 to  $100^\circ C$ .

The polybutadiene has a Mooney viscosity ( $ML_{1+4}$  ( $100^\circ C$ )) of generally at least 40, preferably at least 50, more  
35 preferably at least 52, and most preferably at least 54, but generally not more than 140, preferably not more than 120, more preferably not more than 100, and most preferably not

more than 80. At a Mooney viscosity outside of the above range, the rubber composition may be more difficult to work and the resulting solid core may have a lower resilience.

The term "Mooney viscosity" used herein refers in each case to an industrial index of viscosity (see JIS K6300) as measured with a Mooney viscometer, which is a type of rotary plastometer. This value is represented by the symbol  $ML_{1+4}(100^{\circ}C)$ , wherein "M" stands for Mooney viscosity, "L" stands for large rotor (L-type), and "1+4" stands for a pre-heating time of 1 minute and a rotor rotation time of 4 minutes. The "100°C" indicates that measurement was carried out at a temperature of 100°C.

According to a preferred embodiment of the invention, the polybutadiene may be a modified polybutadiene obtained by polymerization using the above-described rare-earth catalyst, followed by the reaction of a terminal modifier with active end groups on the polymer.

Any known terminal modifier may be used. Examples include terminal modifiers of types (1) to (7) below.

(1) Alkoxysilyl group-bearing compounds, and preferably alkoxysilane compounds having at least one epoxy group or isocyanate group on the molecule. Specific examples include epoxy group-bearing alkoxysilanes such as

3-glycidyloxypropyltrimethoxysilane,

3-glycidyloxypropyltriethoxysilane,

(3-glycidyloxypropyl)methyldimethoxysilane,

(3-glycidyloxypropyl)methyldiethoxysilane,

$\beta$ -(3,4-epoxycyclohexyl)trimethoxysilane,

$\beta$ -(3,4-epoxycyclohexyl)triethoxysilane,

$\beta$ -(3,4-epoxycyclohexyl)methyldimethoxysilane,

$\beta$ -(3,4-epoxycyclohexyl)ethyldimethoxysilane,

condensation products of

3-glycidyloxypropyltrimethoxysilane and condensation products of (3-glycidyloxypropyl)methyldimethoxysilane; and

isocyanate group-bearing alkoxysilane compounds such as

3-isocyanatopropyltrimethoxysilane,

3-isocyanatopropyltriethoxysilane,  
 (3-isocyanatopropyl)methyldimethoxysilane,  
 (3-isocyanatopropyl)methyldiethoxysilane,  
 condensation products of 3-isocyanatopropyltrimethoxysilane  
 5 and condensation products of  
 (3-isocyanatopropyl)methyldimethoxysilane.

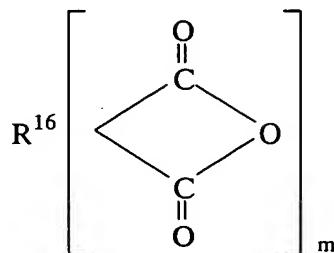
A Lewis acid can be added to accelerate the reaction  
 when the above alkoxysilyl group-bearing compound is reacted  
 with active end groups. The Lewis acid acts as a catalyst to  
 10 promote the coupling reaction, thus improving cold flow by  
 the modified polymer and providing a better shelf stability.  
 Examples of suitable Lewis acids include dialkyltin dialkyl  
 malates, dialkyltin dicarboxylates and aluminum trialkoxides.

Other types of terminal modifiers that may be used  
 15 include:  
 (2) halogenated organometallic compounds, halogenated  
 metallic compounds and organometallic compounds of the  
 general formulas  $R_n^5M'X_{4-n}$ ,  $M'X_4$ ,  $M'X_3$ ,  $R_n^5M'(-R^6-COOR^7)_{4-n}$  or  
 $R_n^5M'(-R^6-COR^7)_{4-n}$  (wherein  $R^5$  and  $R^6$  are each independently a  
 20 hydrocarbon group of 1 to 20 carbons;  $R^7$  is a hydrocarbon  
 group of 1 to 20 carbons which may contain pendant carbonyl  
 or ester groups;  $M'$  is a tin, silicon, germanium or  
 phosphorus atom;  $X$  is a halogen atom; and  $n$  is an integer  
 from 0 to 3);  
 25 (3) heterocumulene compounds having on the molecule a  $Y=C=Z$   
 linkage (wherein  $Y$  is a carbon, oxygen, nitrogen or sulfur  
 atom; and  $Z$  is an oxygen, nitrogen or sulfur atom);  
 (4) three-membered heterocyclic compounds containing on the  
 molecule the following bonds



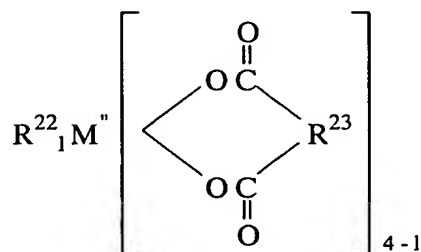
30 (wherein  $Y$  is an oxygen, nitrogen or sulfur atom);  
 (5) halogenated isocyano compounds;  
 (6) carboxylic acids, acid halides, ester compounds,  
 carbonate compounds and acid anhydrides of the respective

formulas  $R^8-(COOH)_m$ ,  $R^9(COX)_m$ ,  $R^{10}-(COO-R^{11})_m$ ,  $R^{12}-OCOO-R^{13}$  and  $R^{14}-(COOCO-R^{15})_m$ , and compounds of the formula



(wherein  $R^8$  to  $R^{16}$  are each independently a hydrocarbon group of 1 to 50 carbons, X is a halogen atom, and m is an integer from 1 to 5); and

(7) carboxylic acid metal salts of the formula  $R^{17}_1M''(OCOR^{18})_{4-1}$  or  $R^{19}_1M''(OCO-R^{20}-COOR^{21})_{4-1}$ , and compounds of the formula



(wherein  $R^{17}$  to  $R^{23}$  are each independently a hydrocarbon group of 1 to 20 carbons,  $M''$  is a tin, silicon or germanium atom, and 1 is an integer from 0 to 3).

The above terminal modifiers and methods for their reaction are described in, for example, JP-A 11-35633, JP-A 7-268132 and JP-A 2002-293996.

Of the above catalysts, rare-earth catalysts, and especially neodymium catalysts, are especially preferred.

It is advantageous for the polybutadiene used in the invention to have a polydispersity index  $M_w/M_n$  (where  $M_w$  is the weight-average molecular weight and  $M_n$  is the number-average molecular weight) of at least 2.0, preferably at least 2.2, more preferably at least 2.4, and most preferably at least 2.6, but not more than 8.0, preferably not more than 7.5, more preferably not more than 4.0, and

most preferably not more than 3.4. If the polydispersity index  $M_w/M_n$  is too low, the rubber composition may be more difficult to work. On the other hand, if  $M_w/M_n$  is too large, the solid core may have a lower resilience.

5           In the practice of the invention, component A is a base rubber composed primarily of the above-described polybutadiene. The polybutadiene content within the base rubber is at least 60 wt%, preferably at least 70 wt%, more preferably at least 80 wt%, and most preferably at least 85  
10 wt%. The content of the above polybutadiene in the base rubber may be as much as 100 wt%, although the polybutadiene content can be set to 95 wt% or less, or in some cases 90 wt% or less. At a polybutadiene content within the base rubber of less than 60 wt%, the core has a poor resilience.

15           In addition to the above-described polybutadiene, the base rubber serving as component A may include also other polybutadienes, such as polybutadienes prepared using a group VIII metal compound catalyst, and other diene rubbers, some examples of which are styrene-butadiene rubber, natural  
20 rubber, isoprene rubber and ethylene-propylene-diene rubber.

          Of the rubber ingredients other than the above-described polybutadiene, the use of a second polybutadiene prepared using a group VIII catalyst and having a Mooney viscosity ( $ML_{1+4}$  (100°C)) of less than 50 and a  
25 viscosity  $\eta$  at 25°C, as a 5 wt% toluene solution, of at least 200 mPa·s but not more than 400 mPa·s is preferable for achieving a high resilience and good workability.

          Group VIII catalysts that may be used include nickel catalysts and cobalt catalysts.

30           Examples of suitable nickel catalysts include single-component systems such as nickel-kieselguhr, binary systems such as Raney nickel/titanium tetrachloride, and ternary systems such as nickel compound/organometallic compound/boron trifluoride etherate. Exemplary nickel  
35 compounds include reduced nickel on a carrier, Raney nickel, nickel oxide, nickel carboxylate and organonickel complex salts. Exemplary organometallic compounds include

trialkylaluminum compounds such as triethylaluminum, tri-n-propylaluminum, triisobutylaluminum and tri-n-hexylaluminum; alkylolithium compounds such as n-butyllithium, sec-butyllithium, tert-butyllithium and 1,4-dilithiumbutane; and dialkylzinc compounds such as diethylzinc and dibutylzinc.

Examples of suitable cobalt catalysts include the following composed of cobalt or cobalt compounds: Raney cobalt, cobalt chloride, cobalt bromide, cobalt iodide, cobalt oxide, cobalt sulfate, cobalt carbonate, cobalt phosphate, cobalt phthalate, cobalt carbonyl, cobalt acetylacetonate, cobalt diethyldithiocarbamate, cobalt anilinium nitrite and cobalt dinitrosyl chloride. It is particularly advantageous to use these compounds in combination with, for example, a dialkylaluminum monochloride such as diethylaluminum monochloride or diisobutylaluminum monochloride; a trialkylaluminum such as triethylaluminum, tri-n-propylaluminum, triisobutylaluminum or tri-n-hexylaluminum; an alkylaluminum sesquichloride such as ethylaluminum sesquichloride; or aluminum chloride.

Polymerization using the group VIII catalysts described above, and especially a nickel or cobalt catalyst, can generally be carried out by a process in which the catalyst is continuously charged into the reactor together with a solvent and the butadiene monomer. The reaction conditions are suitably selected from a temperature range of 5 to 60°C and a pressure range of atmospheric pressure to 70 plus atmospheres, so as to yield a product having the above-indicated Mooney viscosity.

The second polybutadiene has a Mooney viscosity of less than 50, preferably no more than 48, and most preferably no more than 45. It is advantageous for the lower limit in the Mooney viscosity to be at least 10, preferably at least 20, more preferably at least 25, and most preferably at least 30.

The second polybutadiene has a viscosity  $\eta$  at 25°C, as a 5 wt% solution in toluene, of at least 200 mPa·s,

preferably at least 210 mPa·s, more preferably at least 230 mPa·s, and most preferably at least 250 mPa·s, but not more than 400 mPa·s, preferably not more than 370 mPa·s, more preferably not more than 340 mPa·s, and most preferably not  
5 more than 300 mPa·s.

In the invention, the "viscosity  $\eta$  at 25°C as a 5 wt% solution in toluene" (in mPa·s) refers to the value obtained by dissolving 2.28 g of the polybutadiene to be measured in 50 ml of toluene and using as the reference fluid a standard  
10 fluid for viscometer calibration (JIS Z8809) to carry out measurement at 25°C with the requisite viscometer.

The second polybutadiene is typically included in the base rubber in an amount of 0% or more, preferably at least 5%, and more preferably at least 10% by weight, but not more  
15 than 40%, preferably not more than 30%, even more preferably not more than 20%, and most preferably not more than 15% by weight.

It is preferable to use at least two kinds of organic peroxide as component B in the invention. If (a) represents  
20 the organic peroxide having the shortest half-life at 155°C, (b) represents the organic peroxide having the longest half-life at 155°C, and the half-lives of (a) and (b) are denoted as  $a_t$  and  $b_t$  respectively, it is desirable for the half-life ratio  $b_t/a_t$  to be at least 7, preferably at least 8,  
25 more preferably at least 9, and most preferably at least 10, but not more than 20, preferably not more than 18, and most preferably not more than 16. Even with the use of two or more organic peroxides, at a half-life ratio outside of the above range, the desired level of rebound, compression and  
30 durability may not be achieved.

It is desirable for (a) to have a half-life  $a_t$  at 155°C of at least 5 seconds, preferably at least 10 seconds, and most preferably at least 15 seconds, but not more than 120 seconds, preferably not more than 90 seconds, and most  
35 preferably not more than 60 seconds. It is desirable for (b) to have a half-life  $b_t$  at 155°C of at least 300 seconds, preferably at least 360 seconds, and most preferably at least

420 seconds, but not more than 800 seconds, preferably not more than 700 seconds, and most preferably not more than 600 seconds.

Specific examples of suitable organic peroxides include dicumyl peroxide, 1,1-bis(t-butylperoxy)-3,5,5-trimethylcyclohexane and  $\alpha,\alpha'$ -bis(t-butylperoxy)diisopropylbenzene. These organic peroxides may be commercially available products, such as Percumil D (available from NOF Corporation), Perhexa 3M (NOF Corporation) and Luperco 231XL (available from Atochem Co.). The use of 1,1-bis(t-butylperoxy)-3,5,5-trimethylcyclohexane as above organic peroxide (a) and dicumyl peroxide as above organic peroxide (b) is preferred.

The overall amount of organic peroxide, including (a) and (b) above, per 100 parts by weight (abbreviated hereinafter as "parts") of component A, is at least 0.1 part, preferably at least 0.2 part, more preferably at least 0.3 part, and most preferably at least 0.4 part, but not more than 0.8 part, preferably not more than 0.7 part, more preferably not more than 0.6 part, and most preferably not more than 0.5 part. Too little organic peroxide increases the time required for crosslinking, substantially lowering both productivity and compression. On the other hand, too much organic peroxide lowers the rebound and durability of the ball.

In the practice of the invention, by using in the golf ball core a polybutadiene synthesized using a rare-earth catalyst, and especially a neodymium catalyst, and by setting the amount of organic peroxide used in the core within the above-indicated range, the golf ball of the invention can be conferred with excellent rebound characteristics. Such an increase in rebound allows the solid core or the golf ball as a whole to be made correspondingly softer, resulting in desirable initial conditions on a full shot with a driver (i.e., low spin and high angle of elevation) as well as increased carry. Moreover, a soft feel on impact can also be achieved.

The amount of organic peroxide (a) included in the solid core per 100 parts of component A is preferably at least 0.05 part, more preferably at least 0.08 part, and most preferably at least 0.1 part, but preferably not more than 0.5 part, more preferably not more than 0.4 part, and most preferably not more than 0.3 part. The amount of organic peroxide (b) included per 100 parts of component A is preferably at least 0.05 part, more preferably at least 0.15 part, and most preferably at least 0.2 part, but preferably not more than 0.7 part, more preferably not more than 0.6 part, and most preferably not more than 0.5 part.

Component C in the invention is an unsaturated carboxylic acid and/or a metal salt thereof. Examples of suitable unsaturated carboxylic acids include acrylic acid, methacrylic acid, maleic acid and fumaric acid. Acrylic acid and methacrylic acid are especially preferred. Examples of suitable metal salts of the unsaturated carboxylic acids include zinc salts and magnesium salts. Of these, zinc acrylate is especially preferred.

The amount of component C per 100 parts of component A is generally at least 10 parts, preferably at least 15 parts, and most preferably at least 20 parts, but generally not more than 60 parts, preferably not more than 50 parts, more preferably not more than 45 parts, and most preferably not more than 40 parts. An amount of component C outside of the above range may compromise the rebound characteristics and feel upon impact of the golf ball.

Component D in the invention is an organic sulfur compound. Exemplary organic sulfur compounds include thiophenols, thionaphthols, halogenated thiophenols, and metal salts thereof. Specific examples include pentachlorothiophenol, pentafluorothiophenol, pentabromothiophenol, p-chlorothiophenol, and the zinc salts thereof; diphenylpolysulfides, dibenzylpolysulfides, dibenzoylpolysulfides, dibenzothiazoylpolysulfides and dithiobenzoylpolysulfides having 2 to 4 sulfurs; alkylphenyldisulfides, furan ring-bearing sulfur compounds

and thiophene ring-bearing sulfur compounds.

Diphenyldisulfide and the zinc salt of pentachlorothiophenol are especially preferred.

The amount of component D per 100 parts of component A is generally at least 0.1 part, preferably at least 0.2 part, more preferably at least 0.4, and most preferably at least 0.7 part, but generally not more than 5 parts, preferably not more than 4 parts, more preferably not more than 3 parts, even more preferably not more than 2 parts, and most preferably not more than 1.5 parts. The addition of too little component D may fail to have a resilience-improving effect, whereas too much component D may result in a low hardness and insufficient resilience.

Component E in the invention is an inorganic filler, illustrative examples of which include zinc oxide, barium sulfate and calcium carbonate. The amount of component E per 100 parts of component A is generally at least 5 parts, preferably at least 7 parts, more preferably at least 10 parts, and most preferably at least 13 parts, but generally not more than 80 parts, preferably not more than 65 parts, more preferably not more than 50 parts, and most preferably not more than 40 parts. The use of too much or too little component E may make it impossible to achieve a golf ball having the proper weight and a desirable rebound.

If necessary, the rubber composition containing above components A to E may include also an antioxidant. The amount of antioxidant added per 100 parts of component A is generally at least 0.05 part, preferably at least 0.1 part, and more preferably at least 0.2 part, but not more than 3 parts, preferably not more than 2 parts, more preferably not more than 1 part, and most preferably not more than 0.5 part.

The antioxidant may be a commercially available product, such as Nocrac NS-6, Nocrac NS-30 (both made by Ouchi Shinko Chemical Industry Co., Ltd.), and Yoshinox 425 (made by Yoshitomi Pharmaceutical Industries, Ltd.).

The solid core of the inventive golf ball is produced from a rubber composition containing above components A to E

by a process that preferably involves vulcanization and curing of the rubber composition. For example, vulcanization may be carried out at a temperature of 100 to 200°C for a period of 10 to 40 minutes.

5       The solid core formed as described above has a localized hardness which can be adjusted as appropriate and is not subject to any particular limitation. That is, the core thus formed may have a localized hardness profile which is flat from the center to the surface of the core, or which  
10       varies from the center to the surface.

      It is desirable for the solid core to have a diameter of at least 30 mm, preferably at least 32 mm, and most preferably at least 34 mm, but not more than 40 mm, preferably not more than 39 mm, and most preferably not more  
15       than 38 mm. A solid core diameter of less than 30 mm compromises the feel upon impact and the rebound of the golf ball. On the other hand, at a solid core diameter of more than 40 mm, the ball has a poor durability to cracking.

      The solid core has a deflection, when subjected to a  
20       load of 980 N (100 kg), of at least 3.0 mm, preferably at least 3.5 mm, more preferably at least 4.0 mm, and most preferably at least 4.2 mm, but not more than 6.0 mm, preferably not more than 5.8 mm, more preferably not more than 5.5 mm, and most preferably not more than 5.3 mm. A  
25       deflection of less than 3.0 mm worsens the feel upon impact and, particularly on long shots such as with a driver in which the ball incurs a large deformation, subjects the ball to an excessive increase in spin, reducing the carry. On the other hand, at a deflection of more than 6.0 mm, the golf  
30       ball has a less lively feel when hit and an inadequate rebound that results in a poor carry, in addition to which it has a poor durability to cracking with repeated impact.

      It is recommended that the solid core have a specific gravity ( $\text{g/cm}^3$ ) of generally at least 0.9, preferably at  
35       least 1.0, and most preferably at least 1.1, but not more than 1.4, preferably not more than 1.3, and most preferably not more than 1.2.

According to one preferred embodiment, the thermoplastic resin composition used to form the mantle of the inventive golf ball is a polyester elastomer. According to another preferred embodiment, the thermoplastic resin composition is made of 100 parts by weight of resin components which include a base resin of (P) an olefin/unsaturated carboxylic acid binary random copolymer and/or a metal ion neutralization product of an olefin/unsaturated carboxylic acid binary random copolymer in admixture with (Q) an olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer and/or a metal ion neutralization product of an olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer in a weight ratio P/Q of 100:0 to 25:75, and (R) a non-ionomeric thermoplastic elastomer in a weight ratio (P+Q)/R of 100:0 to 50:50; (S) 5 to 80 parts by weight of a fatty acid and/or fatty acid derivative having a molecular weight of 280 to 1,500; and (T) 0.1 to 10 parts by weight of a basic inorganic metal compound capable of neutralizing un-neutralized acid groups in the base resin and component S.

The olefins in the above base resin, both in component P and component Q, have a number of carbons that is generally at least 2, but not more than 8, and preferably not more than 6. Suitable examples include ethylene, propylene, butene, pentene, hexene, heptene and octene. Ethylene is especially preferred.

Illustrative examples of the unsaturated carboxylic acid include acrylic acid, methacrylic acid, maleic acid and fumaric acid. Acrylic acid and methacrylic acid are especially preferred.

The unsaturated carboxylic acid ester is preferably a lower alkyl ester of the unsaturated carboxylic acid. Specific examples include methyl methacrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, methyl acrylate, ethyl acrylate, propyl acrylate and butyl acrylate.

Butyl acrylate (n-butyl acrylate, i-butyl acrylate) is especially preferred.

The olefin/unsaturated carboxylic acid binary random copolymer of component P and the olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer of component Q (the copolymers in components P and Q are hereinafter referred to collectively as "random copolymers") can each be obtained by suitably formulating the above materials and using a known method to carry out random copolymerization.

It is recommended that the above random copolymers be prepared such as to have a specific unsaturated carboxylic acid content (sometimes referred to hereinafter as the "acid content"). The amount of unsaturated carboxylic acid included within the random copolymer of component P is generally at least 4 wt%, preferably at least 6 wt%, more preferably at least 8 wt%, and most preferably at least 10 wt%, but generally not more than 30 wt%, preferably not more than 20 wt%, more preferably not more than 18 wt%, and most preferably not more than 15 wt%.

Similarly, it is recommended that the amount of unsaturated carboxylic acid included within the random copolymer of component Q be generally at least 4 wt%, preferably at least 6 wt%, and most preferably at least 8 wt%, but not more than 15 wt%, preferably not more than 12 wt%, and most preferably not more than 10 wt%. If the random copolymers have too low an acid content, the resilience may decline. On the other hand, too high an acid content may lower the processability of the thermoplastic resin composition.

The metal ion neutralization product of an olefin/unsaturated carboxylic acid binary random copolymer in component P and the metal ion neutralization product of an olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester ternary random copolymer in component Q (the metal ion neutralization products of copolymers in components P and Q are hereinafter referred to collectively as "metal

ion-neutralized random copolymers") can be obtained by partially neutralizing the acid groups on the random copolymer with metal ions.

5 Illustrative examples of metal ions for neutralizing the acid groups include  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Li}^+$ ,  $\text{Zn}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$  and  $\text{Pb}^{2+}$ . Preferred metal ions include  $\text{Na}^+$ ,  $\text{Li}^+$ ,  $\text{Zn}^{2+}$  and  $\text{Mg}^{2+}$ . The use of  $\text{Zn}^{2+}$  is especially recommended.

10 In the practice of the invention, the metal ion-neutralized random copolymers may be prepared by neutralization with the above metal ions. For example, use may be made of a neutralization method that involves the use of compounds such as the formates, acetates, nitrates, carbonates, bicarbonates, oxides, hydroxides or alkoxides of the above metal ions. The degree of neutralization of the  
15 random copolymer by these metal ions is not subject to any particular limitation.

In this invention, the metal ion-neutralized random copolymers are preferably zinc ion-neutralized ionomer resins. Such ionomer resins increase the melt flow rate of the  
20 material, facilitate adjustment to the subsequently described optimal melt flow rate, and thus enable the moldability of the thermoplastic resin composition to be improved.

Commercial products may be used in the base resin made up of above components P and Q. Examples of commercial  
25 products that may be used as the random copolymer in component P include Nucrel 1560, Nucrel 1214 and Nucrel 1035 (all products of DuPont-Mitsui Polychemicals Co., Ltd.); and Escor 5200, Escor 5100 and Escor 5000 (all products of ExxonMobil Chemical). Examples of commercial products that  
30 may be used as the random copolymer in component Q include Nucrel AN4311 and Nucrel AN4318 (both products of DuPont-Mitsui Polychemicals Co., Ltd.); and Escor ATX325, Escor ATX320 and Escor ATX310 (all products of ExxonMobil Chemical).

35 Examples of commercial products that may be used as the metal ion-neutralized random copolymer in component P include Himilan 1554, Himilan 1557, Himilan 1601, Himilan

1605, Himilan 1706 and Himilan AM7311 (all products of DuPont-Mitsui Polychemicals Co., Ltd.), Surlyn 7930 (produced by E.I. du Pont de Nemours and Co., Inc.) and Iotek 3110 and Iotek 4200 (both products of ExxonMobil Chemical). Examples  
5 of commercial products that may be used as the metal ion-neutralized random copolymer in component Q include Himilan 1855, Himilan 1856 and Himilan AM7316 (all products of DuPont-Mitsui Polychemicals Co., Ltd.), Surlyn 6320, Surlyn 8320, Surlyn 9320 and Surlyn 8120 (all products of E.I.  
10 du Pont de Nemours and Co., Inc.), and Iotek 7510 and Iotek 7520 (both products of ExxonMobil Chemical). Examples of zinc-neutralized ionomer resins that can be preferably used as the above metal ion-neutralized random copolymers include Himilan 1706, Himilan 1557 and Himilan AM7316.

15 When the above-described base resin is prepared, the weight ratio P/Q of component P to component Q must be set at from 100:0 to 25:75, preferably from 100:0 to 50:50, more preferably from 100:0 to 75:25, and most preferably 100:0. Too little component P lowers the resilience of the molded  
20 material.

In addition, by adjusting the relative proportions of random copolymer and metal ion-neutralized random copolymer metal in the base resin of above components P and Q, the moldability of the thermoplastic resin composition can be  
25 further improved. It is recommended that that the ratio of random copolymer to metal ion-neutralized random copolymer be generally from 0:100 to 60:40, preferably from 0:100 to 40:60, more preferably from 0:100 to 20:80, and most preferably 0:100. The presence of too much random copolymer may lower  
30 the processability during mixing.

Component R is a non-ionomeric thermoplastic elastomer which is optionally included to further enhance both the feel of the golf ball upon impact and its rebound characteristics. In the invention, the above-described base resin and  
35 component R are referred to collectively as the "resin components." Specific examples of non-ionomeric thermoplastic elastomers that may be used as component R

include olefin elastomers, styrene elastomers, polyester elastomers, urethane elastomers and polyamide elastomers. The use of olefin elastomers and polyester elastomers is preferred for further increasing resilience.

5           Examples of commercial products that may be used as component R include olefin elastomers such as Dynaron (manufactured by JSR Corporation) and polyester elastomers such as Hytrel (manufactured by DuPont-Toray Co., Ltd.).

10           It is recommended that the amount of component R per 100 parts of the base resin in the thermoplastic resin composition be at least 0 part, preferably at least 1 part, more preferably at least 2 parts, even more preferably at least 3 parts, and most preferably at least 4 parts, but not more than 100 parts, preferably not more than 60 parts, more  
15           preferably not more than 40 parts, and most preferably not more than 20 parts. Too much component R may lower the compatibility of the mixture and markedly compromise the durability of the golf ball.

20           The mantle in the inventive golf ball can alternatively be made of a polyester elastomer alone. The polyester elastomer used in such a case may be a material similar to above-described component R. Polyester elastomers suitable for this purpose include Hytrel (manufactured by DuPont-Toray Co., Ltd.).

25           Next, component S in the thermoplastic resin composition is a fatty acid or fatty acid derivative having a molecular weight of 280 to 1,500. This component has a very low molecular weight compared to the base resin and is used to adjust the melt viscosity of the mixture to a suitable  
30           level, particularly to help improve flow. Component S has a relatively high content of acid groups (or derivatives thereof) and is able to suppress an excessive loss of resilience.

35           The molecular weight of the fatty acid or fatty acid derivative of component S is at least 280, preferably at least 300, more preferably at least 330, and most preferably at least 360, but not more than 1,500, preferably not more

than 1,000, more preferably not more than 600, and most preferably not more than 500. Too low a molecular weight may prevent a better heat resistance from being achieved, whereas too high a molecular weight may make it impossible to improve  
5 flow.

Preferred examples of the fatty acid or fatty acid derivative serving as component S include unsaturated fatty acids having a double bond or triple bond on the alkyl group and derivatives thereof, and saturated fatty acids in which  
10 all the bonds on the alkyl group are single bonds and derivatives thereof. It is recommended that the number of carbons on the molecule be generally at least 18, preferably at least 20, more preferably at least 22, and most preferably at least 24, but not more than 80, preferably not more than  
15 60, more preferably not more than 40, and most preferably not more than 30. Too few carbons may prevent a better heat resistance from being achieved and may also make the content of acid groups so high as to diminish the flow-enhancing effect on account of interactions between acid groups in  
20 component S and acid groups present in the base resin. On the other hand, too many carbons increases the molecular weight, which may also prevent the flow-enhancing effect from being achieved.

Specific examples of fatty acids that may be used as  
25 component S include stearic acid, 12-hydroxystearic acid, behenic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid and lignoceric acid. Of these, stearic acid, arachidic acid, behenic acid and lignoceric acid are preferred. Behenic acid is especially preferred.

30 Fatty acid derivatives which may be used as component S include metallic soaps in which the proton on the acid group of the fatty acid has been substituted with a metal ion. Metal ions that may be used in such metallic soaps include  $\text{Na}^+$ ,  $\text{Li}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Sn}^{2+}$ ,  
35  $\text{Pb}^{2+}$  and  $\text{Co}^{2+}$ . Of these,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{Zn}^{2+}$  are preferred.

Specific examples of fatty acid derivatives that may be used as component S include magnesium stearate, calcium

stearate, zinc stearate, magnesium 12-hydroxystearate, calcium 12-hydroxystearate, zinc 12-hydroxystearate, magnesium arachidate, calcium arachidate, zinc arachidate, magnesium behenate, calcium behenate, zinc behenate, 5 magnesium lignocerate, calcium lignocerate and zinc lignocerate. Of these, magnesium stearate, calcium stearate, zinc stearate, magnesium arachidate, calcium arachidate, zinc arachidate, magnesium behenate, calcium behenate, zinc behenate, magnesium lignocerate, calcium lignocerate and zinc 10 lignocerate are preferred.

Moreover, known metallic soap-modified ionomers, including those described in U.S. Pat. No. 5,312,857, U.S. Pat. No. 5,306,760 and International Application WO 98/46671, may be used as the base resin (above components P and Q) in 15 combination with above component S.

Component T is a basic inorganic metal compound which can neutralize acid groups in the base resin and component S. When a metallic soap-modified ionomer resin (e.g., the metallic soap-modified ionomer resins mentioned in the 20 above-cited prior-art patent publications) is used alone without including component T, the metallic soap and the un-neutralized acid groups present on the ionomer resin undergo exchange reactions during mixture under heating, generating a large amount of fatty acid. Because the fatty 25 acid has a low thermal stability and readily vaporizes during molding, it may cause molding defects. Moreover, it adheres to the surface of the molded article, which can substantially lower paint film adhesion.

To overcome such problems and improve the resilience 30 of the molded mantle, it is essential to include a basic inorganic metal compound (component T) which neutralizes acid groups present in the base resin and in component S.

That is, incorporating above component T in the thermoplastic resin composition results in a suitable degree 35 of neutralization of the acid groups in the base resin and in component S. Moreover, optimizing the various components in this way produces synergistic effects which increase the

thermal stability of the mixture, impart a good processability and make it possible to enhance the resilience of the mantle.

It is recommended that the basic inorganic metal compound used as component T be one which has a high reactivity with the base resin and includes no organic acids in the reaction by-products, thus enabling the degree of neutralization of the mixture to be increased without a loss of thermal stability.

Illustrative examples of the metal ions in the basic inorganic metal compound serving as component T include  $\text{Li}^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Sn}^{2+}$ ,  $\text{Pb}^{2+}$  and  $\text{Co}^{2+}$ . Known basic inorganic fillers containing these metal ions may be used as the basic inorganic metal compound. Specific examples include magnesium oxide, magnesium hydroxide, magnesium carbonate, zinc oxide, sodium hydroxide, sodium carbonate, calcium oxide, calcium hydroxide, lithium hydroxide and lithium carbonate. A hydroxide or a monoxide is recommended. Calcium hydroxide and magnesium oxide, both of which have a high reactivity with the base resin, are preferred. Calcium hydroxide is especially preferred.

In the golf ball of the invention, the above-described thermoplastic resin composition which makes up the mantle having at least one layer is arrived at by blending specific respective amounts of components S and T with the resin components, i.e., the base resin containing specific respective amounts of components P and Q, and optional component R. Such a thermoplastic resin composition has excellent thermal stability, flow properties and moldability, and can provide the molded article with a markedly improved resilience.

Components S and T are compounded in respective amounts, per 100 parts by weight of the resin components suitably formulated from components P, Q and R, of at least 5 parts by weight, preferably at least 10 parts by weight, more preferably at least 15 parts by weight, and most preferably at least 18 parts by weight, but not more than 80 parts by

weight, preferably not more than 40 parts by weight, more preferably not more than 25 parts by weight, and most preferably not more than 22 parts by weight, of component S; and at least 0.1 part by weight, preferably at least 0.5 part by weight, more preferably at least 1 part by weight, and most preferably at least 2 parts by weight, but not more than 10 parts by weight, preferably not more than 8 parts by weight, more preferably not more than 6 parts by weight, and most preferably not more than 5 parts by weight, of component T. Too little component S lowers the melt viscosity, resulting in inferior processability, whereas too much lowers the durability. Too little component T fails to improve thermal stability and resilience, whereas too much instead lowers the heat resistance of the thermoplastic resin composition due to the presence of excess basic inorganic metal compound.

In the above-described thermoplastic resin composition which is typically used to form the mantle of the inventive golf ball and is preferably formulated from the respective indicated amounts of the foregoing resin components and components S and T, it is recommended that at least 50 mol%, preferably at least 60 mol%, more preferably at least 70 mol%, and most preferably at least 80 mol%, of the acid groups be neutralized. A high degree of neutralization such as this makes it possible to more reliably suppress the exchange reactions that cause trouble when only a base resin and a fatty acid or fatty acid derivative are used as in the above-cited prior art, thus preventing the formation of fatty acid. As a result, there is obtained a material of greatly increased thermal stability and good processability which can provide a mantle of much better resilience than prior-art ionomer resins.

"Degree of neutralization," as used above, refers to the degree of neutralization of acid groups present within the mixture of the base resin and the fatty acid or fatty acid derivative serving as component S, and differs from the degree of neutralization of the ionomer resin itself when an

ionomer resin is used as the metal ion-neutralized random copolymer in the base resin. A mixture according to the invention having a certain degree of neutralization, when compared with an ionomer resin by itself having the same  
5 degree of neutralization, contains a very large number of metal ions. This large number of metal ions increases the density of ionic crosslinks that contribute to improved reactivity, making it possible to confer the molded article with excellent resilience.

10 To more reliably achieve both a high degree of neutralization and good flow characteristics, it is recommended that the acid groups in the above-described mixture be neutralized with transition metal ions and with  
alkali metal and/or alkaline earth metal ions. Although  
15 transition metal ions have a weaker ionic cohesion than alkali metal and alkaline earth metal ions, the combined use of these different types of ions to neutralize acid groups in the mixture can provide a substantial improvement in the flow properties of the thermoplastic resin composition.

20 The molar ratio between the transition metal ions and the alkali metal and/or alkaline earth metal ions may be adjusted as appropriate. It is recommended that the ratio be within a range of generally 10:90 to 90:10, preferably 20:80 to 80:20, more preferably 30:70 to 70:30, and most preferably  
25 40:60 to 60:40. Too low a molar ratio of transition metal ions may fail to provide sufficient improvement in the flow characteristics of the thermoplastic resin composition. On the other hand, too high a molar ratio may lower the resilience of the mantle molded from the composition.

30 Specific, non-limiting, examples of the metal ions include zinc ions as the transition metal ions and at least one type of ion selected from among sodium, lithium and magnesium ions as the alkali metal or alkaline earth metal ions.

35 A known method may be used to obtain a mixture in which the desired amount of acid groups have been neutralized with transition metal ions and alkali metal or alkaline earth

metal ions. Specific examples of methods of neutralization with transition metal ions, particularly zinc ions, include the use of zinc soaps as the fatty acid derivative, the use of zinc-neutralized products (e.g., zinc ion-neutralized ionomer resins) when formulating component P and component Q as the base resin, and the use of zinc compounds such as zinc oxide as the basic inorganic metal compound of component T.

In the golf ball of the invention, the above-described thermoplastic resin composition from which the mantle having at least one layer is typically made may include also suitable amounts of any additives that may be required for the intended use of the material. For example, if the material is to be used as a cover stock, such additives as pigments, dispersants, antioxidants, ultraviolet absorbers and light stabilizers may be added to the essential ingredients described above. When such additives are included in the composition, they may be incorporated in an amount, per 100 parts by weight of the essential ingredients of the composition (the resin components and components S and T), of preferably at least 0.1 part by weight, more preferably at least 0.5 part by weight, and most preferably at least 1 part by weight, but not more than 10 parts by weight, preferably not more than 6 parts by weight, and most preferably not more than 4 parts by weight.

The thermoplastic resin composition may be obtained by preparing a mixture of the above-described essential ingredients and whatever optional ingredients may be needed, then heating and working together the mixture under suitable conditions, such as a heating temperature of 150 to 250°C and using an internal mixer such as a kneading-type twin-screw extruder, a Banbury mixer or a kneader. Any suitable method may be used without particular limitation to blend various additives with the above-described essential ingredients of the invention. For example, the additives may be combined with the essential ingredients, and heating and mixture of all the ingredients carried out at the same time. Alternatively, the essential ingredients may first be heated

and mixed, following which the optional additives may be added and the overall composition subjected to additional heating and mixture.

The thermoplastic resin composition should have a melt  
5 flow rate adjusted to ensure flow characteristics that are particularly suitable for injection molding and thus improve moldability. Specifically, it is recommended that the melt flow rate, as measured according to JIS-K7210 at a temperature of 190°C and under a load of 21.18 N (2.16 kgf),  
10 be set to generally at least 0.5 dg/min, preferably at least 1 dg/min, more preferably at least 1.5 dg/min, and even more preferably at least 2 dg/min, but generally not more than 20 dg/min, preferably not more than 10 dg/min, more preferably not more than 5 dg/min, and most preferably not more than 3  
15 dg/min. Too large or small a melt flow rate may result in a marked decline in melt processability.

The above thermoplastic resin composition is preferably characterized also in terms of its relative absorbance in infrared absorption spectroscopy, representing  
20 the ratio of absorbance at the absorption peak attributable to carboxylate anion stretching vibrations normally detected at 1530 to 1630  $\text{cm}^{-1}$  to the absorbance at the absorption peak attributable to carbonyl stretching vibrations normally detected at 1690 to 1710  $\text{cm}^{-1}$ . For the sake of clarity, this  
25 ratio may be expressed as follows: (absorbance of absorption peak for carboxylate anion stretching vibrations)/(absorbance of absorption peak for carbonyl stretching vibrations).

Here, "carboxylate anion stretching vibrations" refers to vibrations by carboxyl groups from which the proton has  
30 dissociated (metal ion-neutralized carboxyl groups), whereas "carbonyl stretching vibrations" refers to vibrations by undissociated carboxyl groups. The ratio between these respective peak intensities depends on the degree of neutralization. In the ionomer resins having a degree of  
35 neutralization of about 50 mol% which are commonly used, the ratio between these peak absorbances is about 1:1.

To improve the thermal stability, flow, processability and resilience of the thermoplastic resin composition used in the invention, it is recommended that the composition have a carboxylate anion stretching vibration peak absorbance which is at least 1.3 times, preferably at least 1.5 times, and most preferably at least 2 times, the carbonyl stretching vibration peak absorbance. The absence of any carbonyl stretching vibration peak is especially preferred.

The thermal stability of the thermoplastic resin composition can be measured by thermogravimetry. It is recommended that, in thermogravimetry, the composition have a weight loss at 250°C, based on the weight of the composition at 25°C, of generally not more than 2 wt%; preferably not more than 1.5 wt%, and most preferably not more than 1 wt%.

A known method may be used to form a mantle of at least one layer from the above-described thermoplastic resin composition. The method is not subject to any particular limitation and may be, for example, a process in which a prefabricated core is placed within a mold, and the thermoplastic resin composition, after being heated, mixed and melted, is injection molded about the core. Such a process is highly desirable because it allows production of the golf ball to be carried out in a state where excellent flow properties and moldability are assured. Moreover, the resulting golf ball has a high rebound.

Alternatively, a method may be employed in which the thermoplastic resin composition serving as the mantle-forming material is pre-molded into a pair of hemispherical half-cups, following which the half-cups are placed around the core and molded under applied pressure at 120 to 170°C for a period of 1 to 5 minutes.

The mantle composed of at least one layer has a thickness per layer of at least 0.5 mm, and preferably at least 0.7 mm, but not more than 2.0 mm, and preferably not more than 1.8 mm. At a thickness per mantle layer of less than 0.5 mm, the presence of a mantle has substantially no effect. On the other hand, a thickness per layer of more

than 2.0 mm compromises the feel on impact and the rebound of the ball.

In the mantle having at least one layer, the mantle layer in contact with the cover (outermost layer of the mantle) has a Shore D hardness of at least 20, and preferably at least 25, but not more than 60, and preferably not more than 58. At a Shore D hardness in the outermost layer of the mantle of less than 20, the rebound of the ball decreases. On the other hand, at a Shore D hardness of more than 60, the feel of the golf ball at the time of impact is greatly diminished.

It is critical that the Shore D hardness of the outermost layer of the mantle in the inventive golf ball be no greater than the subsequently described Shore D hardness of the cover. This relationship between the Shore D hardness of the outermost layer of the mantle and the shore D hardness of the cover enables a lower spin and a higher angle of elevation to be achieved in the golf ball. Moreover, when an ionomer resin having a high degree of neutralization is used as the mantle-forming material, a high rebound is also achieved. These effects work together to provide a good carry.

Preferably the mantle consists of an inner layer and an outer layer.

It is preferable for the thermoplastic resin composition used to form the mantle in the inventive golf ball to be either a polyester elastomer or a thermoplastic resin composition formulated from above-described components P to T. By using such thermoplastic resin compositions, the resulting golf ball can be imparted with both a soft feel and a good flight performance.

The golf ball of the invention has a cover made of a material composed of a heated mixture of (F) at least one selected from the group consisting of olefin/unsaturated carboxylic acid copolymers, olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymers and metal ion neutralization products thereof, (G) a polyurethane

elastomer and (H) an organic or inorganic basic compound. This material is sometimes referred to hereinafter as the "cover stock."

5 The olefin in above component F generally has at least 2 carbons but preferably not more than 8 carbons and more preferably not more than 6 carbons. Specific examples include ethylene, propylene, butene, pentene, hexene, heptene and octene. Ethylene is especially preferred.

10 Suitable examples of the unsaturated carboxylic acid in component F include acrylic acid, methacrylic acid, maleic acid and fumaric acid. Acrylic acid and methacrylic acid are especially preferred.

15 The unsaturated carboxylic acid ester in component F is preferably a lower alkyl ester of the above-described unsaturated carboxylic acid. Specific examples include methyl methacrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, methyl acrylate, ethyl acrylate, propyl acrylate and butyl acrylate. Butyl acrylate (n-butyl acrylate, i-butyl acrylate) is especially preferred.

20 The copolymer serving as component F can be prepared by subjecting the above ingredients to random copolymerization by a known method. It is recommended that the olefin/unsaturated carboxylic acid copolymer in component F have an unsaturated carboxylic acid content (sometimes  
25 referred to hereinafter as the "acid content") of generally at least 4 wt%, preferably at least 6 wt%, more preferably at least 8 wt%, and most preferably at least 10 wt%, but not more than 30 wt%, preferably not more than 20 wt%, more preferably not more than 18 wt%, and most preferably not more  
30 than 15 wt%. An acid content which is low may lower the resilience of the cover, whereas one that is high may lower the processability of the cover stock. It is also recommended that the olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymer in component  
35 F have an unsaturated carboxylic acid content ("acid content") of generally at least 4 wt%, preferably at least 6 wt%, and more preferably at least 8 wt%, but not more than 15

wt%, preferably not more than 12 wt%, and most preferably not more than 10 wt%. Here too, an acid content which is low may lower the resilience of the cover, whereas one that is high may lower the processability of the cover stock.

5       The metal ion neutralization products of the above copolymers in component F can be obtained by partially neutralizing the acid groups on the olefin/unsaturated carboxylic acid copolymer or the olefin-unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymer.

10       Illustrative examples of metal ions for neutralizing the acid groups include Na<sup>+</sup>, K<sup>+</sup>, Li<sup>+</sup>, Zn<sup>2+</sup>, Cu<sup>2+</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, Co<sup>2+</sup>, Ni<sup>2+</sup> and Pb<sup>2+</sup>. Preferred metal ions include Na<sup>+</sup>, Li<sup>+</sup>, Zn<sup>2+</sup>, Mg<sup>2+</sup> and Ca<sup>2+</sup>. The degree of neutralization of the above copolymers by these metal ions is not subject to any particular limitation.

15       These neutralization products may be prepared by a known method, such as one involving the use of compounds such as the formates, acetates, nitrates, carbonates, bicarbonates, oxides, hydroxides or alkoxides of the above metal ions.

20       Examples of commercial products that may be used as the olefin/unsaturated carboxylic acid copolymer in component F include Nucrel 1560, Nucrel 1214 and Nucrel 1035 (all products of DuPont-Mitsui Polychemicals Co., Ltd.); and Escor 5200, Escor 5100 and Escor 500 (all products of ExxonMobil Chemical). Examples of commercial products that may be used as the olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymer in component F include Nucrel AN4311 and Nucrel AN4318 (both products of DuPont-Mitsui Polychemicals Co., Ltd.); and Escor ATX325, Escor ATX320 and Escor ATX310 (all products of ExxonMobil Chemical).

30       Examples of commercial products that may be used as the olefin/unsaturated carboxylic acid copolymer metal ion neutralization product in component F include Himilan 1554, Himilan 1557, Himilan 1601, Himilan 1605, Himilan 1706 and Himilan AM7311 (all products of DuPont-Mitsui Polychemicals Co., Ltd.), and Surlyn 7930 (produced by E.I. du Pont de Nemours and Co., Inc.). Examples of commercial products that may be used as the olefin/unsaturated carboxylic

acid/unsaturated carboxylic acid ester copolymer metal ion neutralization product in component F include Himilan 1855, Himilan 1856 and Himilan AM7316 (all products of DuPont-Mitsui Polychemicals Co., Ltd.), Surlyn 6320, Surlyn 8320, Surlyn 9320 and Surlyn 8120 (all products of E.I. du Pont de Nemours and Co., Inc.), and Iotek 7510 and Iotek 7520 (both products of ExxonMobil Chemical).

The olefin/unsaturated carboxylic acid copolymers, olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymers and metal ion neutralization products thereof may be used alone or combinations of two or more of these may be used together. The weight ratio of the olefin/unsaturated carboxylic acid copolymer or a metal ion neutralization product thereof to the olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymer or a metal ion neutralization product thereof is generally from 100:0 to 25:75, preferably from 100:0 to 50:50, more preferably from 100:0 to 75:25, and most preferably 100:0. At a weight ratio smaller than 25:75 (representing less than 25 parts by weight of the olefin/unsaturated carboxylic acid copolymer or a neutralization product thereof per 100 parts by weight of both types of copolymer or their neutralization products combined), the resilience may decrease.

In cases where the olefin/unsaturated carboxylic acid copolymer or olefin/unsaturated carboxylic acid/unsaturated carboxylic acid ester copolymer of above component F is used together with a metal ion neutralization product thereof, the weight ratio of the copolymer to the metal ion neutralization product, while not subject to any particular limitation, is generally from 0:100 to 60:40, preferably from 0:100 to 40:60, more preferably from 0:100 to 20:80, and most preferably 0:100. At a weight ratio larger than 60:40 (representing more than 60 parts by weight of the copolymer per 100 parts by weight of the copolymer and the neutralization product thereof combined), processability during mixing may decline.

Component G used in the cover stock for the inventive golf ball is a polyurethane elastomer. The polyurethane

elastomer, though not subject to any particular limitation, is generally a thermoplastic polyurethane elastomer, a polyurethane powder or a thermoset polyurethane elastomer. The use of a thermoplastic polyurethane elastomer or a  
5 polyurethane powder is especially preferred.

Thermoplastic polyurethane elastomers which may be used in the invention preferably have a structure that is composed in particular of a polymeric polyol compound that forms soft segments, a monomolecular chain extender that  
10 forms hard segments, and a diisocyanate.

Any polymeric polyol compound may be used without particular limitation. Suitable examples include polyester polyols, polyol polyols, polyether polyols, copolyester polyols and polycarbonate polyols. Preferred polyester  
15 polyols include polycaprolactone glycol, poly(1,2-ethylene adipate) glycol and poly(1,4-butylene adipate) glycol. Preferred copolyester polyols include poly(diethylene glycol adipate) glycol. Preferred polycarbonate polyols include poly(1,6-hexanediol carbonate) glycol. Preferred polyether  
20 polyols include polyoxytetramethylene glycol. These polymeric polyol compounds have a number-average molecular weight of generally about 600 to 5,000, and preferably 1,000 to 3,000.

The diisocyanate used in the cover is preferably an  
25 aliphatic or aromatic diisocyanate. Illustrative examples include hexamethylene diisocyanate, 2,2,4- and 2,4,4-trimethylhexamethylene diisocyanate, lysine diisocyanate, tolylene diisocyanate and diphenylmethane diisocyanate. For good compatibility when blending with the  
30 other resins, the use of hexamethylene diisocyanate or diphenylmethane diisocyanate is especially preferred.

The monomolecular chain extender, which is not subject to any particular limitation, may be an ordinary polyhydric alcohol or polyamine. Specific examples include  
35 1,4-butylene glycol, 1,2-ethylene glycol, 1,3-propylene glycol, 1,6-hexylene glycol, 1,3-butylene glycol,

dicyclohexylmethylethanediamine (hydrogenated MDI) and isophoronediamine (IPDA).

5 The above thermoplastic polyurethane elastomer has a JIS A hardness of preferably 70 to 100, more preferably 80 to 99, even more preferably 90 to 99, and most preferably 95 to 98. At a JIS A hardness of less than 70, the ball may take on excessive spin when hit with a driver, resulting in a shorter carry.

10 No limitation is imposed on the specific gravity of the thermoplastic polyurethane elastomer, so long as it is suitably controlled within a range that allows the objects of the invention to be achieved. The specific gravity is preferably from 1.0 to 1.3, and most preferably from 1.1 to 1.25.

15 The above-described thermoplastic polyurethane elastomer may be a commercial product. Illustrative examples include Pandex T7298, Pandex EX7895, Pandex T7890 and Pandex T8198 (all manufactured by DIC Bayer Polymer, Ltd.).

20 Polyurethane powders that may be used in the invention include those composed of fine, spherical particles of polymer. In such microspherical polymers, the individual particles do not cohere to each other, allowing the powder to easily disperse within the base ionomer resin. These polymers can thus impart qualities intrinsic to polyurethanes, such as flexibility, toughness, scratch resistance and weather resistance, without compromising the properties of the cover stock. Moreover microspherical polymers have excellent flow properties and slipperiness, and are thus able to significantly improve moldability. Microspherical polymers  
30 suitable for use as the polyurethane powder have an average particle size of generally 0.1 to 100  $\mu\text{m}$ , preferably 0.5 to 60  $\mu\text{m}$ , more preferably 1 to 40  $\mu\text{m}$ , and most preferably 2 to 20  $\mu\text{m}$ . Examples of this type of polymer include the Art Pearl series produced by Negami Kogyo.

35 The above component F and the above polyurethane elastomer used as component G in the cover stock for the

inventive golf ball are used in respective proportions of generally 50 to 99.9 parts by weight and 0.1 to 50 parts by weight, preferably 80 to 99.5 parts by weight and 0.5 to 20 parts by weight, more preferably 85 to 99 parts by weight and 1 to 15 parts by weight, and most preferably 88 to 97 parts by weight and 3 to 12 parts by weight. The use of more than 50 parts by weight of a polyurethane elastomer as component G may lower the resilience, whereas less than 0.1 part by weight may fail to provide the desired effects of such incorporation.

Component H used in the cover stock for the inventive golf ball is an organic or inorganic basic compound such as an amine, amide, imine, nitrile, phenol, thiol, alcohol, basic inorganic metal compound or metallic soap. Of these, an amine is preferred, and an aliphatic primary amine is especially preferred. An aliphatic primary amine is effective for moderating the gelling reaction, in addition to which it contains an alkyl group and thus apparently acts as a lubricant, substantially improving moldability. Commercial products which can be advantageously used as such aliphatic amines include NOF Corporation's Nissan Amine series.

The amount of organic or inorganic basic compound included in the cover stock per 100 parts by weight of the base resin consisting of component F (at least one selected from the group consisting of olefin/unsaturated carboxylic acid copolymers, olefin/unsaturated carboxylic acid/carboxylic acid ester copolymers, and neutralization products thereof) and component G (a polyurethane elastomer) combined is generally from 0.1 to 20 parts by weight, preferably 0.5 to 10 parts by weight, more preferably 1 to 8 parts by weight, and most preferably 2 to 6 parts by weight. More than 20 parts by weight of the organic or inorganic basic compound may lower the resilience, whereas less than 0.1 part by weight may fail to provide a sufficient gelation preventing effect.

To improve the feel of the inventive golf ball upon impact, in addition to the above-described ingredients, the

cover stock used herein may include also various thermoplastic elastomers. Illustrative examples of such thermoplastic elastomers include olefin elastomers, styrene elastomers, polyester elastomers and polyamide elastomers. Of these, olefin elastomers and polyester elastomers are preferred, and olefin elastomers are especially preferred.

When such a thermoplastic elastomer is used in the cover stock, it is generally incorporated in an amount of 1 to 100 parts by weight, preferably 2 to 60 parts by weight, more preferably 3 to 40 parts by weight, and most preferably 4 to 20 parts by weight, per 100 parts by weight of the base resin consisting of component F (at least one selected from the group consisting of olefin/unsaturated carboxylic acid copolymers, olefin/unsaturated carboxylic acid/carboxylic acid ester copolymers, and neutralization products thereof) and component G (a polyurethane elastomer) combined.

If necessary, the above-described cover stock used in the invention may have added thereto various additives, such as pigments, dispersants, antioxidants, ultraviolet absorbers and light stabilizers, insofar as the objects of the invention are achievable.

The cover stock used in the inventive golf ball has a melt index of preferably 0.5 to 30 g/10 min, preferably 1.0 to 10 g/10 min, and most preferably 1.5 to 5 dg/min.

The amount of such additives included in the cover stock per 100 parts by weight of component F is generally 0.1 to 50 parts by weight, preferably 0.5 to 30 parts by weight, and more preferably 1 to 6 parts by weight. The use of too much additive may lower the durability of the cover, whereas the use of too little may fail to provide the desired effects of addition.

The cover obtained from the above-described cover stock has a Shore D hardness of at least 50, and preferably at least 53, but not more than 70, and preferably not more than 64. A Shore D hardness which is too low compromises the rebound of the ball, whereas a Shore D hardness which is too high fails to provide an improved feel and controllability.

"Shore D hardness," as used herein, refers to the hardness measured with a type D durometer as described in ASTM D2240.

The method of preparing the above-described cover stock is not subject to any particular limitation. For  
5 example, the cover stock may be obtained by working together the above components under applied heat at 150 to 250°C using an internal mixer such as a kneading-type twin-screw extruder, a Banbury mixer or a kneader.

When various additives are included in the cover stock  
10 together with above components F and G, any suitable method of incorporation may be used. That is, the additives may be blended together with components F and G, and heated and mixed at the same time. Alternatively, components F and G may first be heated and mixed, then the desired additives  
15 added, followed by further heating and mixing.

The above-described cover stock has outstanding heat resistance, moldability and paint film adhesion, and provides the golf ball with excellent rebound characteristics and an excellent feel upon impact. Combining the soft core and the  
20 cover described above enables the hardness of the golf ball to be lowered without sacrificing carry, thus achieving a soft feel on impact. Moreover, because the golf ball has a lower hardness, the contact surface area between the club and the golf ball at the time of impact increases, dispersing the  
25 force of impact when the ball is hit and thus further enhancing the scuff resistance of the ball.

The multi-piece solid golf balls of the invention are composed of the above-described core, a mantle of at least one layer which is made of the above-described thermoplastic  
30 resin composition and encloses the core, and a cover which is made of the above-described cover stock and encloses the mantle.

As with the formation of the mantle, the method used to form the cover may be one known to the art and is not  
35 subject to any particular limitation. For example, use may be made of a method in which a mantle-covered core is placed within a mold and the cover stock, after being heated, mixed

and melted, is injection molded about the mantle-covered core. Such a process is desirable both because it allows production of the golf ball to be carried out in a state where excellent flow properties and moldability are assured, and because the  
5 resulting golf ball has a high rebound.

Alternatively, a method may be employed in which the cover stock of the invention is pre-molded into a pair of hemispherical half-cups, following which the half-cups are placed around the mantle-covered core and molded under  
10 applied pressure at 120 to 170°C for a period of 1 to 5 minutes.

The cover formed from the cover stock has a thickness of at least 0.5 mm, preferably at least 0.9 mm, and most preferably at least 1.1 mm, but not more than 2.5 mm and  
15 preferably not more than 2.0 mm. A cover which is too thick has a diminished resilience, whereas one that is too thin has a poor durability.

In the multi-piece solid golf ball of the invention, it is desirable for the surface of the cover to have numerous  
20 dimples formed thereon, and for the cover to be administered various treatment such as surface preparation, stamping and painting. The arrangement of the dimples is preferably such that a great circle which intersects no dimples cannot be traced on the surface of the golf ball. The existence of  
25 even one great circle which does not intersect any dimples may give rise to variability in the flight of the ball.

It is preferable for the number of dimple types and the total number of dimples to be optimized. Synergistic effects arising from optimization of the number of dimple  
30 types and the total number of dimples enables a golf ball to be achieved which has a more stable trajectory and a better overall flight performance, including carry.

The number of dimple types refers herein to the number of types of dimples of mutually differing diameter and/or  
35 depth. It is recommended that this number of dimple types be generally at least two, and preferably at least three, but not more than eight, and preferably not more than six.

It is also recommended that the total number of dimples on the surface of the golf ball be generally at least 300, and preferably at least 320, but not more than 480, and preferably not more than 455. A total number of dimples that is too low or too high may prevent the optimal amount of lift from being achieved, resulting in a shorter carry.

It is recommended that the golf ball of the invention have an optimized dimple volume occupancy VR and an optimized dimple surface coverage SR, both of which are expressed in percent. These parameters VR and SR, when both optimized, act synergistically to improve the trajectory of the ball and increase its carry, and also to help the ball achieve a proper balance between lift and drag, thus making it possible to provide a better overall flight performance.

The dimple volume occupancy VR is defined as the ratio of the sum of the volumes of individual dimples on the surface of the golf ball to the volume of a hypothetical sphere represented by the surface of the golf ball were it to have no dimples, and is expressed in percent. The multi-piece solid golf ball of the invention has a VR value of generally at least 0.70%, and preferably at least 0.75%, but generally not more than 1.00%, preferably not more than 0.82%, and most preferably not more than 0.79%.

The dimple surface coverage SR is defined as the ratio of the sum of the surface areas of individual dimples, each dimple surface area being circumscribed by an edge of the dimple, to the surface area of the same hypothetical sphere as described above, and is likewise expressed in percent. The inventive golf ball has an SR value of generally at least 70%, and preferably at least 72%, but generally not more than 85%, and preferably not more than 83%.

A VR value or SR value outside of the above respective ranges may prevent an optimal trajectory from being achieved and thus lower the carry of the ball.

The combination of the above-described solid core and cover with the foregoing relatively high-trajectory dimples helps prevent the ball from dropping at too steep an angle

and enables the carry of the ball to be extended in a higher and flatter trajectory.

The above-described dimple volume occupancy VR and dimple surface coverage SR are values obtained from measurements of dimples on a fully manufactured golf ball. For example, when the surface of the ball is subjected to finishing treatment (e.g., painting, stamping) after the cover has been formed, VR and SR are calculated based on the shape of the dimples on the manufactured ball once all such treatment has been completed.

The multi-piece solid golf ball of the invention can be manufactured in accordance with the Rules of Golf for use in competitive play, in which case the ball may be formed to a diameter of not less than 42.67 mm and a weight of not more than 45.93 g, and preferably 45.0 to 45.93 g.

The multi-piece solid golf ball of the invention, which is constructed of the above-described core, mantle and cover and which preferably bears numerous dimples on the surface of the cover thereon, has a deflection when subjected to a load of 980 N (100 kgf) of at least 3.0 mm, preferably at least 3.2 mm, more preferably at least 3.4 mm, and most preferably at least 3.6 mm, but not more than 5.0 mm, preferably not more than 4.8 mm, more preferably not more than 4.6 mm, and most preferably not more than 4.4 mm. At a deflection of less than 3.0 mm, the feel upon impact is poor. Moreover, particularly on long shots with a driver or the like in which the ball undergoes large deformation, the ball takes on too much spin and fails to travel as far. On the other hand, at a deflection of more than 5.0 mm, the ball has a less lively feel and does not exhibit sufficient rebound, resulting in a shorter carry. Moreover, it has a poor durability to cracking with repeated impact.

#### EXAMPLES

The following examples and comparative examples are given by way of illustration and not by way of limitation.

### Examples 1 to 4, Comparative Examples 1 to 3

Solid cores were produced by using the rubber compositions shown in Table 1 and vulcanizing at 155°C for 17 minutes.

5 In each example, a mantle-forming material of the composition shown in Table 2 was mixed in a kneading-type twin-screw extruder at 200°C to form the mantle material in pelletized form. This material was then injected into a mold in which the above solid core had been placed, thereby  
10 producing a mantle-covered solid core.

A material of the composition shown in Table 3 was mixed at 200°C in a kneading-type twin-screw extruder to form the cover stock in pelletized form. The cover stock was then injected into a mold in which the above mantle-covered solid  
15 core had been placed, thereby producing a multi-piece solid golf ball.

Details concerning the combination of dimples arranged on the surface of the cover in each example are shown in Table 4. FIGS. 1 and 2 show various arrangements of dimples  
20 of sets A to C given in Table 4.

Table 5 presents the characteristics of the respective golf balls obtained in these examples.

Table 1: Core

Ingredients (parts by weight)		Example				Comparative Example		
		1	2	3	4	1	2	3
Base rubber	HCBN-13	100	100	100	100			
	BR01					50	50	50
	BR11					50	50	50
Organic peroxide	Perhexa 3M-40	0.3	0.3	0.3	0.3	0.6	0.6	0.6
	Percumil D	0.3	0.3	0.3	0.3	0.6	0.6	0.6
Unsaturated carboxylic acid metal salt	Zinc acrylate	18.8	21.3	23.8	22.1	18.0	22.0	26.5
Organic sulfur compound	Zinc salt of pentachlorothiophenol	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Inorganic filler	Zinc oxide	32.6	31.7	22.7	21.9	32.9	23.4	29.7
Antioxidant	Nocrac NS-6	0.1	0.1	0.1	0.1	0.1	0.1	0.1

HCBN-13: Produced by JSR Corporation. Cis-1,4 content, 96%.  
Mooney viscosity (ML<sub>1+4</sub> (100°C)), 53. Polydispersity  
Mw/Mn, 3.2. Catalyst, neodymium.

BR01: Produced by JSR Corporation. Cis-1,4 content, 96%.  
Mooney viscosity (ML<sub>1+4</sub> (100°C)), 44. Polydispersity  
Mw/Mn, 4.2. Catalyst, nickel. Solution viscosity, 150  
mPa·s.

BR11: Produced by JSR Corporation. Cis-1,4 content, 96%.  
Mooney viscosity (ML<sub>1+4</sub> (100°C)), 44. Polydispersity  
Mw/Mn, 4.1. Catalyst, nickel. Solution viscosity, 270  
mPa·s.

Perhexa 3M-40: Produced by NOF Corporation. Perhexa 3M-40  
is a 40% dilution. The amount of addition is the  
effective weight of the 1,1-bis(t-butylperoxy)-3,3,5-  
trimethylcyclohexane in the dilution added.

Percumil D: Produced by NOF Corporation. Dicumyl peroxide.

Zinc Acrylate: Produced by Nihon Joryu Kogyo K.K.

Zinc Salt of Pentachlorothiophenol: Produced by Tokyo Kasei  
Kogyo Co., Ltd.

Zinc Oxide: Produced by Sakai Chemical Industry Co., Ltd.

Nocrac NS-6: 2,2'-Methylenebis(4-methyl-6-t-butylphenol)  
produced by Ouchi Shinko Chemical Industry Co., Ltd.

Table 2: Mantle

Ingredients (parts by weight)	Example				Comparative Example		
	1	2	3	4	1	2	3
Himilan 1601		65					65
Surlyn 8120	75				75		
Dynaron 6100P	25	35			25		35
Behenic acid	20	20					
Calcium hydroxide	2.3	2.2					
Hytrel 4047			100			100	
Hytrel 4767				100			

Himilan 1601: Produced by DuPont-Mitsui Polychemicals Co., Ltd.

Surlyn 8120: An ionomer resin produced by E.I. DuPont de Nemours and Company.

5 Dynaron 6100P: A crystalline olefin block-bearing block copolymer produced by JSR Corporation.

Behenic acid: Produced by NOF Corporation.

Hytrel 4047: A polyester elastomer produced by DuPont-Toray Co., Ltd.

10 Hytrel 4767: A polyester elastomer produced by DuPont-Toray Co., Ltd.

Table 3: Cover

Ingredients (parts by weight)	Example				Comparative Example		
	1	2	3	4	1	2	3
Himilan 1605	45		45	45			
Himilan 1554	45	45	45	45			
Himilan 1601		45			48	48	
Himilan 1557					52	52	
Surlyn 7930							60
Surlyn 6320							35
Nucrel 9-1							5
Pandex R3080	10	10	10	10			
Amine ABT	3	3	3	3			
Titanium dioxide	2	2	2	2	2	2	2

15

Himilan 1605, 1554, 1601 and 1557: All produced by DuPont-Mitsui Polychemicals Co., Ltd.

Surlyn 7930: An ionomer resin produced by E.I. DuPont de Nemours and Company.

20 Surlyn 6320: An ionomer resin produced by E.I. DuPont de Nemours and Company.

Nucrel 9-1: A ternary acid copolymer produced by E.I. DuPont de Nemours and Company.

Pandex R3080: A thermoplastic polyurethane elastomer  
produced by DIC Bayer Polymer, Ltd.  
Amine ABT: An antigelling agent produced by NOF Corporation.

5

Table 4

Dimple set		A	B	C
Total number of dimples		432	398	432
VR (%)		0.81	0.92	1.03
SR (%)		78.6	74.5	78.6
Number of differing types of dimples		3	4	3
Dimple 1	Diameter	3.9	4.1	3.9
	Depth	0.16	0.19	0.2
	Number	300	48	300
Dimple 2	Diameter	3.4	3.8	3.4
	Depth	0.13	0.18	0.17
	Number	60	254	60
Dimple 3	Diameter	2.6	3.2	2.6
	Depth	0.10	0.16	0.14
	Number	72	72	72
Dimple 4	Diameter		2.4	
	Depth		0.12	
	Number		24	

VR: The ratio in percent of the sum of the individual  
spatial volumes for each dimple below a planar surface  
10 circumscribed by an edge of the dimple to the total  
volume of a hypothetical sphere represented by the  
surface of the golf ball were it to have no dimples.

SR: The ratio in percent of the sum of the individual  
surface areas for each dimple circumscribed by a dimple  
15 edge on a hypothetical sphere were the golf ball to have  
no dimples to the surface area of the hypothetical  
sphere.

Table 5

Ingredients (parts by weight)		Example				Comparative Example		
		1	2	3	4	1	2	3
Core	Diameter (mm)	36.4	36.4	36.4	36.4	36.4	36.4	36.4
	Hardness (mm)	5.2	4.8	4.6	4.9	5.2	4.6	3.5
Mantle	Thickness (mm)	1.65	1.65	1.65	1.65	1.65	1.65	1.65
	Hardness	51	53	40	47	51	40	53
Cover	Thickness (mm)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Hardness	60	57	60	60	60	60	57
Dimple set		A	A	B	A	A	C	A
Ball characteristics	Diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7	42.7
	Weight (g)	45.3	45.3	45.3	45.3	45.3	45.3	45.3
	Hardness (mm)	4.0	3.7	3.8	3.9	4.0	3.8	2.8
Flight Performance	Initial velocity (m/s)	58.3	58.4	58.5	58.4	57.7	58.1	58.4
	Spin (rpm)	2520	2640	2650	2600	2530	2640	3000
	Carry (m)	183.0	184.0	184.5	184.0	180.0	175.5	183.5
	Total distance (m)	210.5	209.5	210.0	211.0	207.0	203.5	207.0
Initial velocity at low temperature	Measured value (m/s)	57.7	57.8	57.9	57.8	56.5	56.9	57.2
	Degree of decline	0.6	0.6	0.6	0.6	1.2	1.2	1.1
Feel	Driver	soft	soft	soft	soft	soft	soft	hard
	Putter	soft	soft	soft	soft	soft	soft	hard
Scuff resistance		OK	OK	OK	OK	OK	OK	NG

Core Diameter (mm): The average of measurements taken at  
5 five different places on the surface of the core.

Core Hardness (mm): The deflection of the core when  
subjected to a load of 980 N (100 kgf).

Mantle Thickness (mm): Calculated as

$$[(\text{diameter of mantle-covered core}) - (\text{core diameter})] \div 2.$$

10 Mantle Hardness: Shore D hardness, as measured in accordance  
with ASTM D-2240.

Cover Thickness (mm): Calculated as

$$[(\text{ball diameter}) - (\text{diameter of mantle-covered core})] + 2.$$

Cover Hardness: Shore D hardness, as measured in accordance with ASTM D-2240.

5 Ball Diameter (mm): The average of measurements taken at five different non-dimple places.

Ball Hardness (mm): The deflection of the ball when subjected to a load of 980 N (100 kgf).

10 Flight Performance and Low-Temperature Flight: The initial velocity, spin rate, carry and total distance for each golf ball were measured when the ball was struck at a head speed of 40 m/s and an ambient temperature of 23°C or 0°C with a driver (W#1) mounted on a swing machine made by Miyamae Co., Ltd. The "degree of decline" is  
15 the value obtained as follows:  $[(\text{initial velocity measured at } 23^{\circ}\text{C}) - (\text{initial velocity measured at } 0^{\circ}\text{C})]$ .

Feel: The feel of each ball when hit with a driver (W#1) and a putter was rated by five top-caliber amateur golfers as "Soft," "Ordinary," or "Hard." The rating assigned  
20 most often to a particular ball was used as that ball's overall rating.

Scuff Resistance: The ball was temperature conditioned to 23°C, then hit at a head speed of 33 m/s with a pitching wedge mounted on a swing machine. After being hit, the  
25 ball was examined visually for signs of damage. The scuff resistance was rated as follows.

OK: Damage was not observed, or was of such a limited degree as to pose no impediment to further use of the ball.

30 NG: Considerable damage, such as surface scuffing and loss of dimples.

As described above and demonstrated in the foregoing examples, the multi-piece solid golf balls of this invention  
35 have a combination of outstanding flight performance, excellent scuff resistance, soft feel on impact, and minimal decline in rebound at low temperature.

Japanese Patent Application No. 2002-349289 is incorporated herein by reference.

Although some preferred embodiments have been described, many modifications and variations may be made thereto in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described without departing from the scope of the appended claims.